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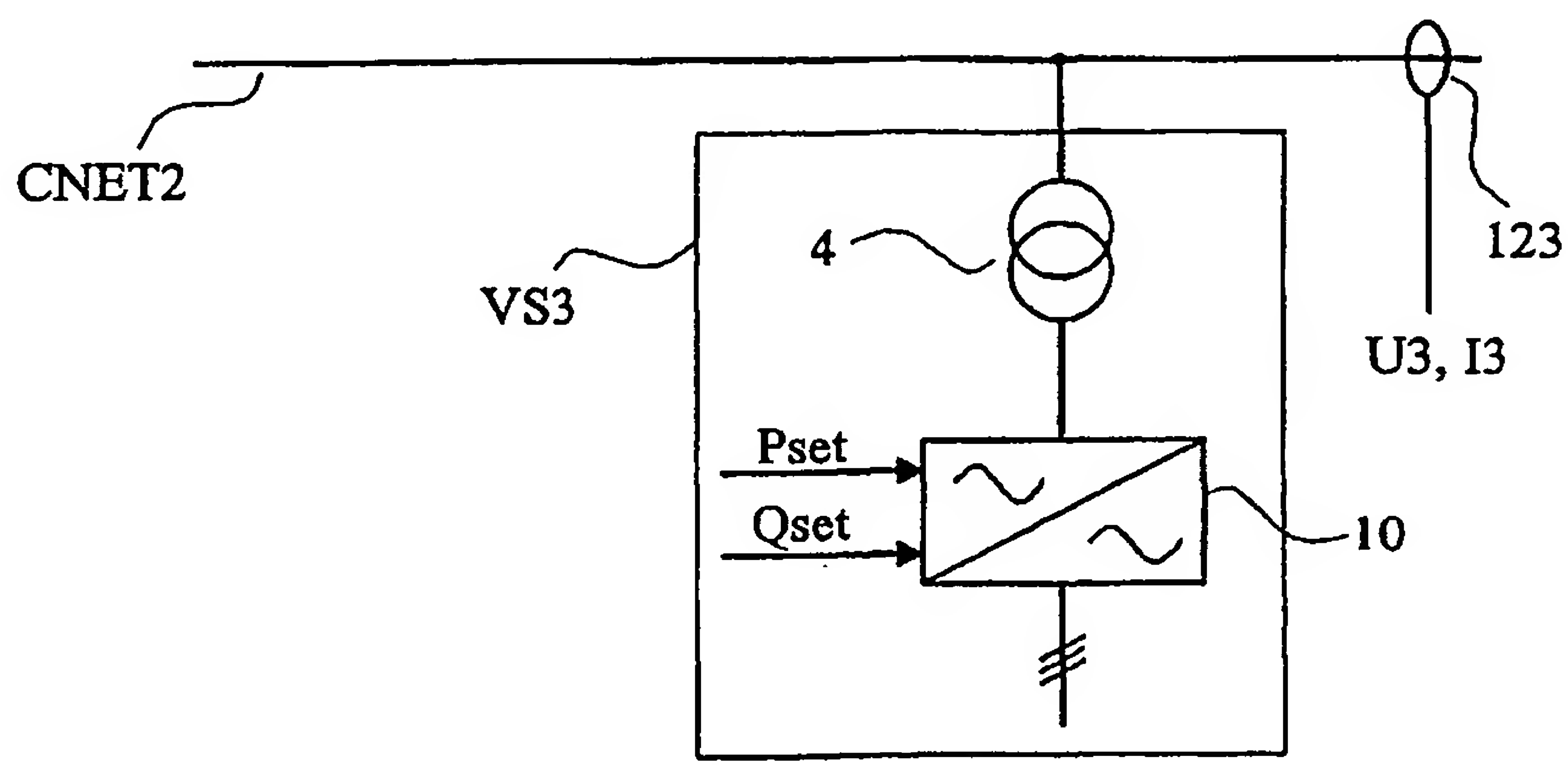
(54) Title: WIND POWER PLANT HAVING FIXED-SPEED AND VARIABLE-SPEED WINDMILLS



(57) Abstract: A wind power plant has at least one fixed-speed windmill (FS1-FS4) and at least one variable-speed windmill (VS1-VS4) which are coupled to a common electric network (CNET1-CNET3, EPG). The variable-speed windmill has a controllable converter means (10) for independent control of active power (P) and of reactive power (Q) supplied to the common electric network, in dependence on an active power set point value (Pset) and a reactive power set point value (Qset). The power plant further has measuring means (121-125) for providing, in a frequency interval that extends above and below a frequency of 8.8 Hz, measured values (U, I) representative of one of a voltage fluctuation and of a fluctuation in active and reactive power at a selected point in the common electric network. The plant further comprises flicker control means (16, 17, 18P, 18Q), responsive to fluctuations in said frequency interval, for receiving the measured values and generating at least one of an active power flicker correction signal (Pcorr, Pcorr') and a reactive power flicker correction signal (Qcorr, Qcorr') in dependence thereon, and means (21p, 21Q) for receiving said at least one flicker correction signal and for forming at least one of the active power set point value and the reactive power set point value in dependence on said at least one active power flicker correction signal.

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Wind power plant having fixed-speed and variable-speed windmills.

TECHNICAL FIELD

The present invention relates to a wind power plant having at least one fixed-speed windmill and at least one variable-speed windmill which are coupled to a common electric network, the variable-speed windmill having a controllable converter means for independent control of active power and of reactive power supplied to the common electric network, in dependence on an active power set point value and a reactive power set point value, the power plant further having measuring means for providing, in a frequency interval that extends above and below a frequency of 8.8 Hz, measured values representative of one of a voltage fluctuation and of a fluctuation in active and reactive power at a selected point in the common electric network. The invention also relates to a method for use in such a wind power plant, a use of a variable-speed windmill in such a wind power plant, and a controllable converter means for such a variable-speed windmill.

BACKGROUND ART

A comprehensive discussion of the above mentioned technical field is to be found in the following articles in Wiley Encyclopedia of Electrical and Electronics Engineering, Volume 23, John Wiley & Sons, 1999, which articles are hereby incorporated by reference:

- Wind power (pages 613-618, by Frede Blaabjerg and Ned Mohan)
- Wind power plants (pages 618- 626, by Nicholas Jensen and Andrew Vaudin)
- Wind turbines (pages 626- 635, by René Spée and Shibashis Bhowmik)

A wind power plant usually comprises a plurality of windmills, each comprising a wind turbine mechanically coupled to an electric generator for conversion of the wind power to electric power. The wind turbines are, in dependence on the local wind conditions, distributed over a given area,

typically in a number of parallel strings perpendicular to the prevailing wind direction, or where no such wind direction is to be found, in a grid layout.

The number of windmills in each string and the distance between adjacent windmills along such a string will depend on the power rating of the windmills and of the power plant as well as on local conditions, typically a string may comprise 5 - 10 windmills with a mutual distance in the order of 300 m.

A power collection system within the wind power plant is formed by coupling the generators along a string to a radial cable running along the string and connecting the radial cables to each other at a so called point of common connection (PCC). Where the local conditions are suitable, at least some of the generators may be coupled to a ring cable coupled to the point of common connection. The power generated by the wind power plant is supplied to an electric power grid, for example a utility grid, of a rated frequency (usually 50 or 60 Hz) and a rated voltage that may typically be at the 132 kV level. Typically, the rated voltage of the cables is 22 kV and the point of common connection is coupled to the electric power grid via a power transformer.

Occasionally, also consumers may be connected to a cable within the power collection system.

Due to the intermittent nature of the available wind power usually all the generated electric power is supplied to the electric power grid.

The windmills may be divided into two categorises, i. e. fixed-speed and variable-speed mills, referring to whether the turbine and the rotor of the electric generator will operate at an at least substantially fixed rotational speed, determined by the frequency of the power grid, or operate with a variable rotational speed adapted to the actual wind conditions and the characteristics of the wind turbine.

Fixed-speed windmills may be equipped with some kind of synchronous generators, such as reluctance machines or conventional synchronous machines, but are, due to mechanical design considerations, more often equipped with induction generators.

Induction generators are of an uncomplicated design requiring only a minimum of control equipment, which also makes them attractive from an economical point of view. However, as those generators are usually designed with a low number of poles, typically 4 or 6, a mechanical gearbox is required to adapt the low rotational speed of the wind turbine to the speed of the generator. The generators will need reactive power for their operation but the control equipment usually comprises only some starting equipment to limit the inrush current when the generator is connected to the power collection system, and phase capacitors, sometimes switchable, coupled to the stator windings of the generator for generation of reactive power during operation. Although the generators may be designed with a pole-changing mechanism, this feature allows only for operation at two different but fixed rotational speeds at the cost of a more complicated winding design.

The electrical energy conversion part of variable-speed mills is adapted to supply electric power of a frequency that is not in a fixed relationship to the rotational speed of the wind turbine. This normally requires use of some power electronics equipment in addition to the generator, which usually is a multi-pole synchronous machine. Thus, a frequency converter may be coupled between the stator terminals of the generator and the power collection system, which allows for a conversion of the voltage and the frequency available at the terminals of the generator to a frequency and a voltage amplitude suitable for coupling the windmill to the power collection system.

Alternatively, and in particular for higher power ratings, double-winded asynchronous machines with the rotor winding available at slip rings on the rotor shaft may be used as generators. By supplying the rotor winding with power of a variable frequency, the frequency and the voltage at the stator windings of the generator can be controlled to a desired frequency, for example the instantaneous frequency of the electric power grid, and to a desired amplitude of the voltage. The system is usually implemented by coupling a frequency converter between the slip rings and that electric system to which the stator windings of the generator are coupled.

Converters suitable for the use as mentioned above may be of different types known per se, for example converters with an intermediate direct current link, often equipped with gate-turn off semiconductor elements such as gate-turn-off thyristors (GTOs) or insulated gate bipolar transistors (IGBTs), or direct frequency converters such as cycloconverters.

The introduction of a frequency converter with control equipment also provides suitable methods for control of reactive power exchange with the transmission network.

Generally, the electric energy conversion part of variable-speed windmills, and in particular the power electronics equipment with control equipment, will render variable-speed windmills more expensive and complicated than the fixed-speed windmills as described above, and thus it is in many cases desirable to use fixed-speed windmills in wind power plants.

The operator of the electric power grid usually has a requirement on the maximum level of the voltage supplied from the wind power plant. However, as mentioned above, usually all the generated electric power is supplied to the grid. In particular with increasing unit sizes of the windmills and with an increasing distance between the wind power plant and the grid, the voltage control at the point of common connection has been identified as a problem. The voltage rise, typically occurring at times of low grid load and high output power from the windmills, is dependent on the short circuit power at the point of common connection and in particular where the wind power plant is equipped with fixed-speed windmills, a situation may arise where it will be necessary to switch off a windmill in order to keep the voltage level within prescribed limits. This of course means an undesirable loss of energy.

In a paper titled 'Possibilities by using a self-commutated voltage source inverter connected to a weak grid in wind parks' (J Svensson, 1996 European Union Wind Energy Conference and Exhibition, Göteborg, 1996, pp 492-495), a wind power plant coupled to an electric power grid is studied, assuming various short circuit ratios and short circuit impedance ratios at the point of common connection. One configuration of the wind power plant has a power collection system comprising a fixed-speed windmill and a variable-speed

windmill, the latter being connected to the power collection system via a self-commutated converter with a dc-link. Results of simulations illustrate the improvements in control of the steady state voltage level at the point of common connection by using the variable-speed windmill for voltage control.

Steady state voltage level control at the point of common connection with a similar wind power plant configuration is also studied in a paper titled "Power Quality in Wind Parks' (G Brauner, Official Proceedings of 5th European power quality conference, Nürnberg, 1998), reporting similar results.

The mechanical torque of the wind turbine is subject to fluctuations, in particular to periodic fluctuations due to the design of the wind turbine, typically at a frequency in the order of 1 - 2 Hz, occasionally even below 1 Hz. A predominant source of such fluctuations is the so-called vortex interaction, see for example a paper by Vladislav Akhmatov and Hans Knudsen: Dynamic modelling of Windmills (IPST '99 - International Conference on Power Systems Transients, June 20-24, 1999, Budapest). However, for example imperfections in the gearbox may be the cause of fluctuations even in higher frequency ranges, typically in the order of up to 8 Hz.

Although the induction generators of a fixed-speed windmill have some inherent damping, such torque fluctuations will, due the consequential fluctuations in the rotational speed of the induction generator, cause fluctuations in the outputted active power of the generator, and, due to the inherent characteristic of such a generator, also in the reactive power exchange with the power collection system, thereby affecting the voltage quality of the electric power grid.

Also in a fixed-speed windmill using a generator of a synchronous type the fluctuations in the mechanical torque of the wind turbine will result in variations in the electrical output of the generator.

If for example a light bulb is coupled to a consumer network that in turn is coupled to the electric power grid, such fluctuations in the output voltage of the generators are visible for the human eye as so-called flicker. In particular where the fluctuations occur in a frequency interval typically 0.5 - 20 Hz, these

fluctuations are observable and disturbing for the human eye. Flicker meters, taking into account the visual perception process of the human eye, have been developed and standardised, having a sensitivity maximum at frequency of 8,8 Hz for sinusoidal fluctuations.

Consequently, operators of utility grids will put - often standardised - restrictions on allowable flicker level. Such restrictions can be so severe that the operation of a wind power plant with only fixed-speed windmills is not technically feasible, or at least impose a limitation of the generating capacity of the wind power plant.

In a paper titled 'Voltage fluctuations caused by windparks' (G Brauner, Paper no. 65, Power Quality '97 Europe, Stockholm 1997), a wind power plant having a power collection system comprising three fixed-speed windmills coupled to a radial cable is studied by simulation. The cable is connected to the electric power grid via a 20/110 kV power transformer located 1 km from the closest windmill. As a remedy against the voltage fluctuations and flicker appearing, it is proposed to increase the short circuit power at the point of common interconnection and/or increase the nominal slip of the induction generators.

Also the per se known fact that synchronous generators with four-quadrant pulse inverters allow for methods for control of active and reactive power exchange with the electric power grid is noted in the paper, stating that with such electric power conversion capabilities network interference due to harmonics and flicker are no more a problem.

However, to effectively increase the short circuit power at the point of common interconnection usually requires a substantial increase in rated power of the power transformer that couples the power collection system of the wind power plant to the electric power grid, with consequential increased costs.

An increase of the nominal slip of the induction generators, i. e. an increase of the resistance of the rotor winding resistance, will result in a lower efficiency for the generator.

In general, in a variable-speed windmill, fluctuations in the outputted active power as caused by torque fluctuations will usually be considerably less, as the power electronics control equipment may be designed to control active as well as reactive power, thereby responding to the fluctuations by minimising their effect on generated voltage and power. The ability to independently control active and reactive power output is in this context considered as a characteristic feature of the variable-speed windmill.

SUMMARY OF THE INVENTION

It is an object of the invention to provide a wind power plant which makes it possible to rely mainly or at least to the greater extent on fixed-speed windmills for the generation of electric power and supply thereof to an electric power grid, such as a utility grid, by way of reducing the influence of the fluctuations in the outputted voltage and power of the generators of the fixed-speed windmills on the power collection system to a level which meets the requirements of the operator of the grid. It is also the object of the invention to provide a method for use in such a wind power plant, a use of a variable-speed windmill in such a wind power plant, and a controllable converter means for such a variable-speed windmill.

According to the invention this object is accomplished in a wind power plant having at least one fixed-speed windmill and at least one variable-speed windmill which are coupled to a common electric network, the variable-speed windmill having a controllable converter means for independent control of active power and of reactive power supplied to the common electric network, in dependence on a an active power set point value and a reactive power set point value, the power plant further having measuring means for providing, in a frequency interval that extends above and below a frequency of 8.8 Hz, measured values representative of one of a voltage fluctuation and of a fluctuation in active and reactive power at a selected point in the common electric network, and wherein the plant comprises flicker control means, responsive to fluctuations in said frequency interval, for receiving the measured values and generating at least one of an active power flicker correction signal and a reactive power flicker correction signal in dependence thereon, and means for receiving said at least one flicker correction signal and

for forming at least one of the active power set point value and the reactive power set point value in dependence on said at least one flicker correction signal.

In a development of the invention said flicker control means generates one active power flicker correction signal and one reactive power flicker correction signal in dependence on the measured values, and said means for receiving said at least one flicker correction signal receives said flicker corrections signals and forms the active power set point value in dependence on said active power flicker correction signal, and forms the reactive power set point value in dependence on said reactive power flicker correction signal.

In a further development of the invention said flicker control means comprises at least one filter means having a band pass characteristics with a pass band in said frequency interval.

In another advantageous development of the invention said frequency interval has a frequency range of 0.5 -20 Hz.

In another development of the invention said at least one filter means has a phase-advancing characteristics in said frequency interval.

In another development of the invention said at least one filter means comprises a filter member having a transfer function substantially similar to the sensitivity characteristics of a standardised flicker meter.

In an advantageous development of the invention said measured values is representative of a voltage fluctuation at said selected point in the common electric network.

In another advantageous development of the invention said measured values are representative of a fluctuation in active and reactive power, and have one component (P) that is representative of active power flow at said selected point, and one component (Q) that is representative of reactive power flow at said selected point.

Further advantageous developments and embodiments of the invention will become clear from the detailed description below and from the accompanying claims.

The following advantages are achieved by the invention.

Where flicker requirements are a limiting factor for installed capacity of the power plant, one or more variable-speed mills can be added to avoid flicker problems caused by fixed-speed mills, thus allowing for increased generation capacity.

The main or at least a great part of the power generated by the wind power plant can be generated by uncomplicated and comparatively inexpensive fixed-speed windmills without giving rise to flicker problems.

By a suitable control system, known per se, the variable-speed windmill will respond to fluctuations in a frequency range that is relevant for the flicker problem.

Under most operating conditions the variable-speed windmill(s) will contribute to the generation of electric power and this without any loss in efficiency due to the power modulations executed in dependence on the flicker control means.

In particular when the active power set point value is formed in dependence on the active power flicker correction signal, and the reactive power set point value is formed in dependence on the reactive power flicker correction signal, a smooth active power flow as well as a smooth reactive power flow will be achieved in the network, which power conditions also imply a smooth voltage.

As a side effect, the variable-speed windmill(s) may also, as is known per se, contribute to the steady state voltage level control of the power collection system.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be explained in greater detail by description of embodiments with reference to the accompanying drawings, which are all schematic and drawn as combined block- and single line diagrams, only showing main components which are of relevance for the understanding of the invention, and wherein

figure 1	shows a known embodiment of a fixed-speed windmill,
figure 2	shows a known embodiment of a variable-speed windmill,
figure 3	shows details of a known embodiment of a controller for a converter means for control of the electric output of a variable-speed windmill,
figure 4	shows an example of a wind power plant and an electric power grid according to the invention,
figure 5A	shows an embodiment of a flicker control means according to the invention,
figure 5B	shows parts of another embodiment of a flicker control means according to the invention,
figure 6A	shows details of an embodiment of filter means comprised in a flicker control means according to figures 5A-5B, and
figure 6B	shows details of another embodiment of filter means comprised in a flicker control means according to figures 5A-5B, and

Same reference numbers and labels are used in the various figures to signify parts that are of the same kind.

DESCRIPTION OF PREFERRED EMBODIMENTS

The following description relates both to the wind power plant and to the method, and the block diagrams can thus be regarded both as signal flow diagrams and block diagrams of a device. The functions to be performed by the blocks shown in the block diagrams may in applicable parts be implemented by means of analogue and/or digital technique in hard-wired circuits, or as programs in a microprocessor. Although the blocks shown in the figures are mentioned as members, filters, devices etc. they are, in particular where their functions are implemented as software for a microprocessor, to be interpreted as means for accomplishing the desired function. Thus, as the case may be, the expression "signal" can also be interpreted as a value generated by a computer program and appearing only as such. Only functional descriptions of the blocks are given below as these functions are either known per se or can be implemented in manners known per se by persons skilled in the art.

In order not to weigh the description and the drawings with distinctions that are obvious for the person skilled in the art, usually the same designations are used for quantities that appear in the electric network and for measured values and signals/calculated values, corresponding to these quantities, that are supplied to and processed in the described control means.

In the block diagrams measured values and blocks for the generation of certain signals used as inputs to other blocks are shown, but connecting lines between measured values and those blocks, and between blocks, are at some places not shown in order not to weigh the drawings. However, it shall be understood that the respective signals are received from the blocks that generate them and that the measured values are generated in a way known per se by sensing corresponding quantities in the electric network.

The blocks shown in some of the figures comprises inter alia calculating members, and it is to be understood that inputs and outputs from the respective blocks may be either of signals and calculated values. Signal and calculated value is thus used synonymously.

Figure 1 shows a fixed-speed windmill having a wind turbine 1, coupled to a three-phase induction generator 2 via a gearbox 3. The stator windings of the generator are via an intermediate transformer 4 coupled to an electric network, only a part of which is shown in the figure as a three-phase cable CNET. Typically, the nominal voltage at the stator windings of the generator is 690 V and the nominal voltage of the cable CNET is 22 kV. The rated frequency of the network is usually 50 or 60 Hz.

A voltage-measuring device 5 senses the voltage Ug at the stator windings of the generator and a current-measuring device 8 senses the current Ig flowing to the cable. A switchable capacitor unit 6, shunt-connected to the stator windings of the generator, is used to control the reactive power exchange between the generator and the cable. The capacitors of the capacitor unit are switched in and out under control of a reactive power control member 7, in which the reactive power flow at the generator is determined from the sensed voltage Ug and the sensed current Ig and compared with a desired value.

The active power output of the windmill is controlled via a per se known pitch control system. The sensed voltage Ug and current Ig are supplied to a pitch controller 9, calculating in dependence thereon the active power delivered by the windmill. In dependence on the active power delivered and a sensed wind velocity w, the pitch controller generates a pitch control signal PC that adjusts the pitch of the turbine blades so that at lower wind velocities the highest possible power output from the windmill will be obtained and when the power output reaches a power limit, the pitch position is so changed that a selected constant power output is obtained.

Figure 2 shows a variable-speed windmill having a wind turbine 1 directly coupled to a three-phase generator 2 of synchronous type. The stator windings of the generator are via a frequency converter 10 and an intermediate transformer 4 coupled to a three-phase cable CNET. The converter is of a type known per se, for example comprising a rectifier for rectifying the voltage supplied by the generator, and a direct current link (not shown in the figure) coupling the rectifier to an inverter which supplies its output voltage to the transformer 4. The converter is controllable such that the voltage supplied to the transformer is controllable to phase and amplitude whereby active power

output and reactive power output from the converter can be controlled independently of each other. A power controller 11 generates a set point value Pset for the active power output and a set point value Qset for the reactive power output. Control equipment for control of the converter in dependence on the set point values are known per se and not shown in the figure.

A voltage-measuring device 5 senses the voltage Uc supplied by the converter to the transformer and a current-measuring device 8 the value of the current Ic flowing from the converter to the transformer.

The rotational speed N of the turbine and the wind speed w are sensed and supplied to a pitch controller 9, which generates a pitch control signal PC so that when the active power output reaches a limit, the pitch of the turbine blades is adjusted to obtain a selected constant power output.

Figure 3 shows an embodiment of the power controller 11 into some detail, and, for the sake of clarity, also the frequency converter 10, the voltage-measuring device 5 and the current-measuring device 8.

A calculating member 111 storing information on the known characteristics of the wind turbine is supplied with a measured value of the wind speed w and calculates in dependence thereon a rotational speed reference value Nref that optimises the active power output from the turbine at the instantaneous wind speed. The speed reference value and the instantaneous value N of the rotational speed are compared in a difference forming member 112, the output of which is supplied to an active power control member 113. The control member 113 comprises typically a control device having a proportional-integrating-derivating type for generating an output signal Pref in dependence on the output of the difference forming member 112. In order not to cause fluctuations in active power at rapidly changing wind- and speed conditions, the rate of change of the output signal is limited to a chosen value, in the figure illustrated by a limiting signal dPref/dt.

The power controller 113 is also supplied with a measured value of the voltage Uc. When this measured value exceeds a chosen voltage limit value the output signal Pref is reduced according to a chosen Pref /Uc-characteristic.

coupled to the cable CNET1 at a point located between the fixed-speed windmills FS1 and the fixed-speed windmills FS2. The three cables are connected to each other at a point PCC of common connection, and at this point the power collection system is coupled to an electric power grid EPG via a power transformer 13. Thus, the windmills are all coupled to a common electric network. As mentioned above, the nominal voltage of the cables CNET1-CNET3 is typically 22 kV whereas the nominal voltage of the electric power grid is typically 132 kV.

A local consumer, in the figure shown as a local network LOCN is coupled to the point of common connection via a power transformer 14.

Measuring means 121 is coupled to the cable CNET1 at a point located between the point of connection to the cable of the variable-speed windmill VS1 and of the fixed-speed windmills FS2, and measuring means 122 is coupled to the cable CNET1 at a location between the point of connection to the cable of the variable-speed windmill VS2 and the point of common connection. Similarly, measuring means 123 is coupled to the cable CNET2 between the point of connection to the cable of the variable-speed windmill VS3 and the point of common connection, and measuring means 124 is coupled to the cable CNET3 between the point of connection to the cable of the variable-speed windmill VS4 and the point of common connection. The measuring means 121-124 sense and provide measured values at least of the respective voltages U1, U2, U3, U4 of the respective cable at the point where the respective measuring means is located. In one embodiment of the invention the measuring means also sense and provide measured values of the respective currents I1, I2, I3, I4 flowing through the respective cable at the same location, thereby making it possible to determine the active and reactive power flow in the respective cable at the respective location.

Figure 5A shows an embodiment of the invention, applied to the variable-speed windmill VS3 that is of the kind described with reference to figure 2. Of the windmill only the frequency converter 10 and the intermediate transformer 4 are shown, and in addition also the measuring means 123 at the cable CNET2. In this embodiment of the invention, it is assumed that the measuring means 123 provides measured values of the voltage U3 and of the current I3 at the

cable. Reference is made also to figures 2-4 with accompanying descriptions above.

As mentioned above, flicker is observable and disturbing for the human eye when appearing in a frequency interval typically 0.5 - 20 Hz, and standardized flicker meters have a sensitivity maximum a frequency of about 8,8 Hz. It is assumed that the measuring means have a corresponding bandwidth.

The measured values of the voltage U3 and of the current I3 are supplied to a calculating unit 17 of a kind known per se, which in dependence thereon calculates and outputs values P of the active power flow and values Q of the reactive power flow at the location of the measuring means (the indexes 3 to P and Q are omitted for the sake of simplicity). As mentioned above, the fixed-speed windmills FS3 will usually introduce fluctuations in the active power outputted by their generators, and also in their reactive power exchange with the power collection system, that is in particular on the cable CNET2. These fluctuations will now be present in the outputted values P and Q of the calculating unit 17 as fluctuations in the respective amplitudes of P and Q.

As described with reference to figure 3, the frequency converter 10 modulates the active and reactive power outputted from the windmill in dependence on its set point values Pset and Qset respectively, which set point values in known embodiments of a variable-speed windmills are set equal to an active power reference signal Pref and to a reactive power reference signal Qref respectively, generated for example as described with reference to figure 3.

According to this embodiment of the invention, an active power flicker correction signal Pcorr′ is now generated and added to the active power reference signal Pref, and a reactive power flicker correction signal Qcorr′ is generated and added to the reactive power reference signal Qref. The active power set point value is thus formed in dependence on the active power flicker correction signal, and the reactive power set point value in dependence on the reactive power flicker correction signal. The flicker correction signals are added to the respective power reference signals with signs in such a way that the outputted active and reactive power of the variable-speed windmill will counteract the fluctuations sensed by the measuring means, thereby improving

the power quality and in particular the presence of flicker on the cable CNET2 at the location of the measuring means.

An example of how such power correction signals may be generated will now be described with reference to figure 5A. The calculated values P are supplied to a filter device 18P having a band pass characteristics, that outputs a signal Pcorr, representing the fluctuations in active power at the location of the measuring means. Although this signal could be used as the active power correction signal mentioned above, it is for practical reasons suitable to limit its amplitude with respect to the power rating of the frequency converter. The output signal of the filter device 18P is thus supplied to a limiting device 19P, which in a per se known way limits the amplitude of the signal Pcorr not to exceed a selected value. The output signal Pcorr′ of the device 19P is then supplied to an adding member 21P, which is also supplied with the active power reference signal Pref generated according to the prior art, for example as described with reference to figure 3.

The sum of the active power reference signal Pref and the active power correction signal Pcorr′, in the figure labelled as Pset, is then supplied to the frequency converter as its active power set point value Pset for active power flowing through it.

In an analogous way, a reactive power correction signal Qcorr′ is generated in dependence on values Q of the reactive power flow at the location of the measuring means, calculated by the calculating unit 17, and processed in a filter device 18Q, and a limiting device 19Q.

The reactive power correction signal Qcorr′ is supplied to an adding member 21Q, which is also supplied with the reactive power reference signal Qref generated according to the prior art, for example as described with reference to figure 3.

The sum of the reactive power reference signal Qref and the reactive power correction signal Qcorr′, in the figure labelled as Qset, is then supplied to the frequency converter as its reactive power set point value Qset for reactive power flow through it.

Figure 5B shows parts of another embodiment of a flicker control means according to the invention. In this embodiment of the invention the measuring means 123 provides measured values only of the voltage U3 at the cable, and the calculating unit 17 is omitted. Fluctuations generated by the fixed-speed windmills FS3 will now be present in the voltage U3 as a fluctuation in its amplitude, and the measured values of the voltage U3 are supplied to the filter device 18P and to the filter device 18Q. In a similar way as described with reference to figure 5A, the filter devices 18P and 18Q output signals Pcorr and Qcorr, respectively, which signals are processed in a similar way as described above.

An advantageous embodiment of the filter devices 18P and 18Q is illustrated in figure 6A. The filter device 18P comprises a filter member 181P and a filter member 182P coupled in cascade. The filter member 181P has a phase-advancing (derivating with respect to time) characteristic, in the figure symbolised with the Laplace-operator s, a time constant T1, in the figure symbolised with the term 1+sT1, and an amplification factor Kp. The filter member 182P has a so-called lead-lag characteristic with a transfer function H(s) of the form $H(s) = K(1 + sT2)/(1 + sT3)$ wherein T2 and T3 are time constants with $T2 < T3$. The time constants in the filter device are chosen in such a way that the device is responsive to frequencies in an interval that extends above and below a frequency of 8.8 Hz, preferably in a frequency range of 0.5 - 20 Hz. A filter member 183P, having a low pass characteristics with a time constant T7, in the figure symbolised with the term 1+sT7, is coupled in cascade with the filter members 181P and 182P to suppress fluctuations of frequencies above the frequency interval of interest for flicker reduction.

The filter device 18Q is of similar kind as the filter device 18P, having filter members 181Q, 182Q and 183Q, however in particular the amplification factor Kq in the member 181Q may have a value that differs from the value of the amplification factor Kp of the filter member 181P.

Another advantageous embodiment of the filter devices 18P and 18Q is illustrated in figure 6B. The filter member 18P comprises in this embodiment a weighting filter member 184P, having a transfer function substantially similar

to the sensitivity characteristics of a standardised flicker meter. As mentioned above, flicker meters taking into account the visual perception process of the human eye, have been developed and standardised, having a sensitivity maximum at frequency of 8,8 Hz for sinusoidal fluctuations. Thus, to take into account this perception process, the specifications for such a flicker meter specifies a particular filter characteristic of the form

$$H_F(s)=\frac{k\omega_1 s}{s^2+2\lambda s+\omega_1^2}*\frac{1+s/\omega_2}{(1+s/\omega_3)(1+s/\omega_4)} \qquad (1)$$

where s is the Laplace-operator, k and λ are constants having the values 1, 74802 and $2\pi*$ 4.05981 respectively. $\omega_1, \omega_2, \omega_3$ and ω_4 expresses characteristic frequencies for the filter, having the values $2\pi*$ 9.15494, $2\pi*$ 2.27979, $2\pi*$ 1.22535 and $2\pi*$ 21.9 respectively.

The filter member 184P is thus in this embodiment of the invention implemented to have a transfer function substantially similar to the filter characteristic $H_F(s)$ according to the expression (1) above.

In this embodiment of the filter device 18P, the member 182P is similar to the member 182P described with reference to figure 6A, whereas the member 181P described with reference to figure 6A is replaced by a member 181P′ with the amplification factor Kp.

Also in this embodiment, the filter device 18Q is of similar kind as the filter device 18P, having filter members 181Q′, 182Q and 184Q, however in particular the amplification factor Kq in the member 181Q′ may have a value that differs from the value of the amplification factor Kp of the filter member 181P′.

The setting of the values of the amplification factors Kp and Kq will usually be determined for each factor individually, preferably in dependence on an analysis of expected fluctuations in active power and reactive power at the selected point of location of the measuring means in the electric network. Such an analysis may be performed by way of calculations and/or simulations.

As mentioned above, it is for practical reasons suitable to limit the amplitude of the flicker corrections signals with respect to the power rating of the frequency converter. The flicker control means will, when such a limit is reached, have a limited effect on the reduction of fluctuations in power flow and voltage, respectively. The values of the amplification factors are thus preferably set so that these limits are not reached under expected normal operating conditions.

In the embodiments of the filter devices 18P and 18Q having filter members 184P and 184Q, respectively, with transfer functions substantially similar to the filter characteristic $H_F(s)$ according to the expression (1) above, the effect will be that fluctuations of frequencies that are most disturbing to the human eye will also be most strongly reduced. Thus, when setting the values of the amplification factors, all the various flicker frequencies expected to appear at the selected point in the electric network have to be considered as well as the influence of the weighting filter members 184P and 184Q on these frequencies.

The time constants T1-T8 of the filter devices 18P and 18Q are set to values such that the filter devices will be responsive to fluctuations in a frequency interval where flicker occurs and can be influenced by the variable-speed windmill.

In particular for the case that the measuring means provides measured values that are representative only of a voltage fluctuation at the selected point in the common electric network, as is described above with reference to figure 5B, and the goal is to reduce flicker at the point of common connection PCC, it is preferable that these measured values are representative of the voltage fluctuations at the same point. This implies that in this case the selected point for location of the measuring means should preferably be at the point of common connection or at a point in the electric network where the impedance between the selected point and the point of common connection is low.

Assuming that the selected point for the measuring means is located so as just mentioned, that the fluctuations appearing in the measured voltage values have their origin mainly in the wind power plant, and that the system impedance of the power grid as well as the relation between active and reactive power variations originating from the wind power plant can be estimated, the following calculations can be performed.

With the power grid represented by a system impedance $Z = R + jX$ and a voltage bus U_{inf}, the voltage fluctuations ΔU, appearing in the measured voltage values, at the selected point for location of the measuring means can be approximately expressed as

$$\Delta U \approx \frac{R}{U_{inf}} * \Delta P + \frac{X}{U_{inf}} * \Delta Q \qquad (2)$$

where ΔP and ΔQ are fluctuations in active and reactive power, respectively, corresponding to the voltage fluctuation s ΔU.

The estimated relation between active and reactive power variations originating from the wind power plant is expressed as

$$\Delta P = \mathrm{K}_r * \Delta \mathrm{Q} \qquad (3)$$

With the expression (3) inserted in the expression (2), the following expression for the active power fluctuations ΔP as a function of the voltage fluctuations ΔU is obtained:

$$\Delta P \approx \frac{U_{inf}}{R + \mathrm{K}_r * X} * \Delta U \qquad (4)$$

The setting of the value of the amplification factor Kp will be done in consideration of the maximum active power fluctuations that are expected to occur in the wind power plant and of the relation between ΔU and ΔP according to the expression (4). The ratio between the amplification factor Kp and the amplification factor Kq will under these assumptions follow the expression (3), that is be equal to the factor K_r.

The expression (2) above indicates two special cases that are of interest in this context.

For a case where the reactive (usually inductive) part X of the system impedance $Z = R + jX$ can be neglected, the expression (2) indicates that the

voltage fluctuations depend only on fluctuations in active power. This implies that in this case the desired reduction of flicker can be achieved by generating only an active power flicker correction signal Pcorr, as possible fluctuations in reactive power will not influence the flicker level.

In the same way, for a case where the resistive part R of the system impedance $Z = R + jX$ can be neglected, the expression (2) indicates that the voltage fluctuations depend only on fluctuations in reactive power. This implies that in this case the desired reduction of flicker can be achieved by generating only a reactive power flicker correction signal Qcorr, as possible fluctuations in active power will not influence the flicker level. These two situations can be handled according to the invention either by omitting that part of the flicker control means that would generate a flicker control signal without influence on the flicker level, or by reducing the correspondent amplification factor to zero or to a very low value.

That is, when for example the resistive part of the system impedance can be neglected, the filter member 18P of figure 5B, as well of course also the limiting member 19P and the adding member 21P of figure 5A, can be omitted from the flicker control means, or alternatively, the amplification factor Kp can be reduced to zero or to a very low value.

Where a great number of fixed-speed windmills are coupled to a common cable, it is preferable to use more than one variable-speed windmill, which additional variable-speed windmills are then located at intermediate positions along the cable. This is in figure 4 illustrated at the cable CNET1, where the variable-speed windmill VS1 is located between the fixed-speed windmills FS1 and the fixed-speed windmills FS2. The power available for flicker reduction in the windmill VS1 can then be used to reduce power fluctuations caused by the windmills FS1, thereby diminishing the requirements for power to reduce flicker in the windmill VS2.

The fixed-speed windmills FS3 and the variable-speed windmill VS3 are in figure 4 shown as coupled to the common line CNET2 of the power collection system at a first junction J1 and a second junction J2, respectively, and the location of the measuring means 121 is selected to be between the second

junction and the point of common connection, that is upstream in the direction of the power flow to the electric power grid. However, it is also possible to achieve a reduction of the power fluctuations appearing at the second junction by selecting the location of the measuring means to be between the first and the second junction.

Figure 4 also shows a location of measuring means 125, which are of the same kind as the measuring means 121-124, at a point between the point of common connection and the power transformer 13. The measured values that are provided by this measuring means are thus representative of the fluctuations appearing at the point of common connection. The measured values of the voltage U and current I are supplied to a calculating unit 15 that is of the same kind as the above described calculating unit 17, thus calculating and outputting values P of the active power flow and values Q of the reactive power flow at the location of the measuring means 125, including fluctuations in their respective amplitudes.

The values P and Q are supplied to a flicker controller means 16 of the same kind as described with reference to figure 5A, outputting limited power corrections signals Pcorrc' and Qcorrc'. In one embodiment of the invention, the flicker controller means 16, that is then common to the wind power plant, supplies the limited power correction signals to all variable-speed windmills in the plant, where they are added to the respective active power and reactive power reference signals.

In still another embodiment of the invention, the measuring means 125 may provide measured values only of the voltage U at the point of common connection. In this embodiment of the invention, the calculating unit 15 is omitted. The measured values of the voltage U are processed as described above with reference to figure 5B, and the corresponding limited flicker correction signals are then supplied to all variable-speed windmills in the plant, where they are added to the respective power reference signals.

The flicker control means as described with reference to figure 5A and the measuring means 121-124, are then not used as individual means for each variable-speed windmill. However, due to for example different ratings and/or

different operating conditions for the various variable-speed windmills, also a combination of a centralised measuring means 125 at the point of common connection and individual flicker control means provided at each variable-speed windmill may be of advantage.

In the wind power plant as illustrated in figure 4, the power collection system has the form of radial cables coupled to a point of common connection. Depending on local conditions, at least some of the windmills may also be coupled to a ring cable. Power and voltage fluctuations are then present everywhere in the ring cable and preferably the measured value of the fluctuations are then provided by only one central measuring means, whereas the flicker control means can be either a common one for all variable-speed windmills coupled to the cable or individual flicker control means provided at each variable-speed windmill.

Usually, when the windmills are connected to the electric network, the phase positions of the fluctuations of the various fixed-speed windmills are all distributed in an uncorrelated manner. Thus, the overall fluctuations sensed at the point of common connection may be small. However, after some time of operation, at least some of the windmills may become closer to synchronism, thereby increasing the risk of flicker at an unacceptable level also at the point of common connection. A centralised localisation of the measuring means at the point of common connection may under such circumstances be of advantage, allowing for an equalisation of the power fluctuations between the windmills internal to the power collection system.

A flicker control based on forming only one of the active and reactive power set point values in dependence on a flicker control means, and where voltage fluctuations caused by fluctuations in active power are cancelled by controlling the reactive power fluctuations or where voltage fluctuations caused by fluctuations in reactive power are cancelled by controlling the active power fluctuations, will have the effect that although the voltage fluctuations at the selected point are reduced, power fluctuations might still exist and might cause voltage fluctuations at other locations in the electric network. Under such circumstances, forming the active power set point value in dependence on the active power flicker correction signal, and the reactive power set point value in

dependence on the reactive power flicker correction signal, will have the effect of reducing voltage fluctuations also at other locations in the electric network that are coupled to the power collection system.

The invention is not limited to the embodiments shown but a number of modifications are feasible within the scope of the claims.

The set point values for active and reactive power must not exceed the power handling capacity of the windmill. For this reason, usually not only the flicker correction signals should be limited but also the power reference signals. In particular when the windmill is operating close to the limit of its active power reference value and at the same time the active power flicker correction signal reaches a high level, it might be feasible to further limit the active power reference signal in dependence on the amplitude of the active power flicker correction signal, thereby creating maximum power handling capacity for reduction of the active power fluctuations according to the invention. Such limitations may be implemented by a person skilled in the art by sensing the amplitude of the active power flicker correction signal, and in dependence thereon apply, preferably delayed by a time constant, a limitation of the power reference signal to a value that is lower the higher the amplitude of the correction signal is.

The fixed-speed and the variable-speed windmills may be of any per se known type and configuration, assumed that the variable-speed windmill is of a type that allows for independent control of active and reactive power.

Also, for example, the flicker control means may be implemented in other ways well known in the art as long as they are responsive in a frequency interval that is relevant for flicker.

The flicker control means may be provided with an enabling unit letting through or blocking, respectively, the limited flicker correction signals in dependence on a manually or automatically generated enabling signal.

Also, the wind power plant may comprise more than one power collection systems, each with a point of common connection and constituting a separate

wind park. Such wind parks may, in particular when they are located in the neighbourhood of each other, be coupled to a common electric power grid. It might then be feasible to equip one of the wind parks only with fixed-speed windmills and one of the wind parks with a combination of fixed-speed and variable-speed windmills. In particular when a flicker control according to the invention is based on a measured value of the active and the reactive power at the selected point for the measuring means, for example at the point of common connection of the wind park having variable-speed windmills, these windmills may be used to reduce also fluctuations caused by the windmills in the wind park having only fixed-speed windmills.

CLAIMS

1. Wind power plant having at least one fixed-speed windmill (FS1-FS4) and at least one variable-speed windmill (VS1-VS4) which are coupled to a common electric network (CNET1-CNET3, EPG), the variable-speed windmill having a controllable converter means (10) for independent control of active power (P) and of reactive power (Q) supplied to the common electric network, in dependence on a an active power set point value (Pset) and a reactive power set point value (Qset), the power plant further having measuring means (121-125) for providing, in a frequency interval that extends above and below a frequency of 8.8 Hz, measured values (U, I) representative of one of a voltage fluctuation and of a fluctuation in active and reactive power at a selected point in the common electric network, characterised in that the plant comprises

flicker control means (16, 17, 18P, 18Q), responsive to fluctuations in said frequency interval, for receiving the measured values and generating at least one of an active power flicker correction signal (Pcorr, Pcorr') and a reactive power flicker correction signal (Qcorr, Qcorr') in dependence thereon, and

means (21p, 21Q) for receiving said at least one flicker correction signal and for forming at least one of the active power set point value and the reactive power set point value in dependence on said at least one flicker correction signal.

2. Wind power plant according to claim 1, characterised in that said flicker control means (16, 17, 18P, 18Q) generates one active power flicker correction signal and one reactive power flicker correction signal in dependence on the measured values, and

said means (21p, 21Q) for receiving said at least one flicker correction signal receives said flicker corrections signals and forms the active power set point value in dependence on said active power flicker correction signal, and forms the reactive power set point value in dependence on said reactive power flicker correction signal.

3. Wind power plant according to any of claims 1-2, characterised in that said flicker control means comprises at least one filter means (18P, 18Q) having a band pass characteristics with a pass band in said frequency interval.

4. Wind power plant according to any of the preceding claims, c h a r a c - t e r i s e d in that said frequency interval has a frequency range of 0.5 - 20 Hz.

5. Wind power plant according to any of claims 1-4, c h a r a c t e r i s e d in that said at least one filter means has a phase-advancing characteristics in said frequency interval.

6. Wind power plant according to claim 5, c h a r a c t e r i s e d in that said at least one filter means comprises a filter member (182P, 182Q) with a transfer function of the form H(s) = Kp(1 + sT2)/(1 + sT3), where s is the Laplace operator, Kp a constant, and T2 and T3, with T2 < T3, are constants corresponding to said frequency interval.

7. Wind power plant according to any of claims 1-4, c h a r a c t e r i s e d in that said at least one filter means comprises a filter member (184P, 184Q) having a transfer function substantially similar to the sensitivity characteristics of a standardised flicker meter.

8. Wind power plant according to any of the preceding claims, c h a r a c t e r i s e d in that said measured values are representative of a voltage fluctuation at said selected point in the common electric network.

9. Wind power plant according to any of claims 1-7, c h a r a c t e r i s e d in that it comprises means (15, 17) for forming and providing values (P, Q) representative of a fluctuation in active and reactive power in dependence on said measured values (U, I), having one component (P) that is representative of active power flow at said selected point, and one component (Q) that is representative of reactive power flow at said selected point.

10. Wind power plant according to any of the preceding claims, wherein the wind power plant has at least two variable-speed windmills, c h a r a c t e - r i s e d in that said flicker control means (16) is common to the at least two variable-speed windmills.

11. Wind power plant according to any of the preceding claims, wherein the common electric network has a power collection system (CNET1-CNET3) common for the windmills, and wherein the fixed-speed windmill and the variable-speed windmill are coupled to a common line (CNET2) of the power collection system at a first (J1) and a second (J2) junction respectively, c h a r a c t e r i s e d in that said selected point in the electric network is located at the common line between the first and the second junction.

12. Wind power plant according to any of the claims 1-9, wherein the common electric network has a power collection system (CNET1-CNET3) common for the windmills, the power collection system for coupling to an electric power grid (EPG) at a point of common connection (PCC), and the fixed-speed windmill and the variable-speed windmill for coupling to the power collection system at a first (J1) and a second (J2) junction respectively, c h a r a c t e r i s e d in that said selected point in the electric network is located at the common line between the second junction and the point of common connection.

13. Wind power plant according to claim 12, c h a r a c t e r i s e d in that said selected point in the electric power network is located such that the measured value is representative of one of a voltage and of a fluctuation in active and reactive power at the point of common connection.

14. Wind power plant according to claim 13, wherein the wind power plant has at least two variable-speed windmills, c h a r a c t e r i s e d in that said flicker control means (16) is common to the at least two variable-speed windmills.

15. Wind power plant according to claim 13, wherein the wind power plant has at least two variable-speed windmills, c h a r a c t e r i s e d in that each of the variable-speed windmills is provided with a flicker control means (17, 18P, 18Q).

16. Method for use in a wind power plant having at least one fixed-speed windmill (FS1-FS4) and at least one variable-speed windmill VS1-VS4) which are coupled to a common electric network (CNET1-CNET3, EPG), the variable-

speed windmill having a controllable converter means (10) for independent control of active power (P) and of reactive power (Q) supplied to the common electric network, in dependence on a an active power set point value (Pset) and a reactive power set point value (Qset), the power plant further having measuring means (121-125) for providing, in a frequency interval that extends above and below a frequency of 8.8 Hz, measured values (U, I) representative of one of a voltage fluctuation and of a fluctuation in active and reactive power at a selected point in the common electric network,
characterised in that the method comprises the steps of

receiving said measured values and generating, in response to fluctuations in said frequency interval, at least one of an active power flicker correction signal (Pcorr, Pcorr') and a reactive power flicker correction signal (Qcorr, Qcorr') in dependence on said measured values, and

forming at least one of the active power set point value and the reactive power set point value in dependence on said at least one flicker correction signal.

17. Method according to claim 16, characterised in that

said step of generating at least one of an active power flicker correction signal and a reactive power flicker correction signal comprises the steps of generating one active power flicker correction signal and one reactive power flicker correction signal in dependence on said measured values, and

said step of forming at least one of the active power set point value and the reactive power set point value in dependence on said at least one active power flicker correction signal comprises the steps of forming the active power set point value in dependence on said active power flicker correction signal, and forming the reactive power set point value in dependence on said reactive power flicker correction signal.

18. Method according to any of claims 16-17, characterised in that said step of generating a flicker correction signal comprises the step of processing said measured values in at least one filter means (18P, 18Q) having a band pass characteristics with a pass band in said frequency interval.

19. Method according to any of claims 16-18, characterised in that said step of generating a flicker correction signal comprises the step of

processing said measured values in at least one filter means (18P, 18Q) having a band pass characteristics with a pass band in said frequency interval which frequency interval has a frequency range of 0.5 - 20 Hz.

20. Method according to any of claims 16-19, characterised in that said step of generating a flicker correction signal comprises the step of processing said measured values in at least one filter means (18P, 18Q) having a phase-advancing characteristics in said frequency interval.

21. Method according to claim 20, characterised in that said step of generating a flicker correction signal comprises the step of processing said measured values in at least one filter means (18P, 18Q) having a filter member with a transfer function of the form $H(s) = K(1 + sT2)/(1 + sT3)$, where s is the Laplace operator, K a constant, and T2 and T3, with $T2 < T3$, are constants corresponding to said frequency interval.

22. Method according to any of claims 16-19, characterised in that said step of generating a flicker correction signal comprises the step of processing said measured values in at least one filter means (18P', 18Q') having a filter member (183P', 183Q') with a transfer function substantially similar to the sensitivity characteristics of a standardised flicker meter.

23. Method according to any of claims 16-22, characterised in that said measured values are representative of a voltage fluctuation at said selected point in the common electric network.

24. Method according to any of claims 16-22, characterised in that values (P, Q) representative of a fluctuation in active and reactive power are formed from said measured values (U, I), having one component (P) that is representative of active power flow at said selected point, and one component (Q) that is representative of reactive power flow at said selected point.

25. Method according to any of claims 16-24, wherein the wind power plant has at least two variable-speed windmills, characterised in that said step of generating at least one flicker correction signal comprises the step of

generating a flicker correction signal that is common to the at least two variable-speed windmills.

26. Method according to any of claims 16-25, wherein the common electric network has a power collection system (CNET1-CNET3) common for the windmills, and wherein the fixed-speed windmill and the variable-speed windmill are coupled to a common line (CNET2) of the power collection system at a first (J1) and a second (J2) junction respectively, characterised in that the method comprises the step of locating said selected point in the electric network at the common line between the first and the second junction.

27. Method according to any of claims 16-24, wherein the common electric network has a power collection system (CNET1-CNET3) common for the windmills, the power collection system for coupling to an electric power grid (EPG) at a point of common connection (PCC), and the fixed-speed windmill and the variable-speed windmill for coupling to the power collection system at a first (J1) and a second (J2) junction respectively, characterised in that the method comprises the step of locating said selected point in the electric network at the common line between the second junction and the point of common connection.

28. Method according to claim 27, characterised in that the method comprises the step of locating said selected point such that the measured value is representative of one of a voltage and of a fluctuation of active and reactive power at the point of common connection.

29. Method according to claim 28, wherein the wind power plant has at least two variable-speed windmills, characterised in that said step of generating at least one flicker correction signal comprises the step of generating a flicker correction signal that is common to the at least two variable-speed windmills.

30. Method according to claim 28, wherein the wind power plant has at least two variable-speed windmills, characterised in that said step of generating at least one flicker correction signal comprises the step of generating a flicker correction signal for each of the variable-speed windmills.

31. Use of a variable-speed windmill (VS1-VS4) in a wind power plant having at least one fixed-speed windmill (FS1-FS4) and at least one variable-speed windmill (VS1-VS4) which are coupled to a common electric network (CNET1-CNET3, EPG), for reduction of one of a voltage fluctuation and of a fluctuation in active and reactive power at a selected point in the electric network, in a frequency interval that extends above and below a frequency of 8.8 Hz and caused by the fixed-speed windmill.

32. Controllable converter means (10) for a variable-speed windmill (VS1-VS4) for coupling to an electric network (CNET1-CNET3, EPG), the converter means (10) having control means for independent control of active power (P) and of reactive power (Q) supplied to the electric network, in dependence on a an active power set point value (Pset) and a reactive power set point value (Qset), converter means (10) for independent control of active power (P) and of reactive power (Q) supplied to the common electric network, in dependence on a an active power set point value (Pset, Pset') and a reactive power set point value (Qset, Qset'), the power plant further having measuring means (121-125) for providing, in a frequency interval that extends above and below a frequency of 8.8 Hz, measured values (U, P, Q) representative of one of a voltage fluctuation and of a fluctuation in active and reactive power at a selected point in the electric network, characterised in that the converter means control means is provided with

flicker control means (16, 17, 18P, 18Q), responsive to fluctuations in said frequency interval, for receiving the measured values and generating at least one of an active power flicker correction signal (Pcorr, Pcorr') and a reactive power flicker correction signal (Qcorr, Qcorr') in dependence thereon, and

means (21p, 21Q) for receiving said at least one flicker correction signal and for forming at least one of the active power set point value and the reactive power set point value in dependence on said at least one flicker correction signal.

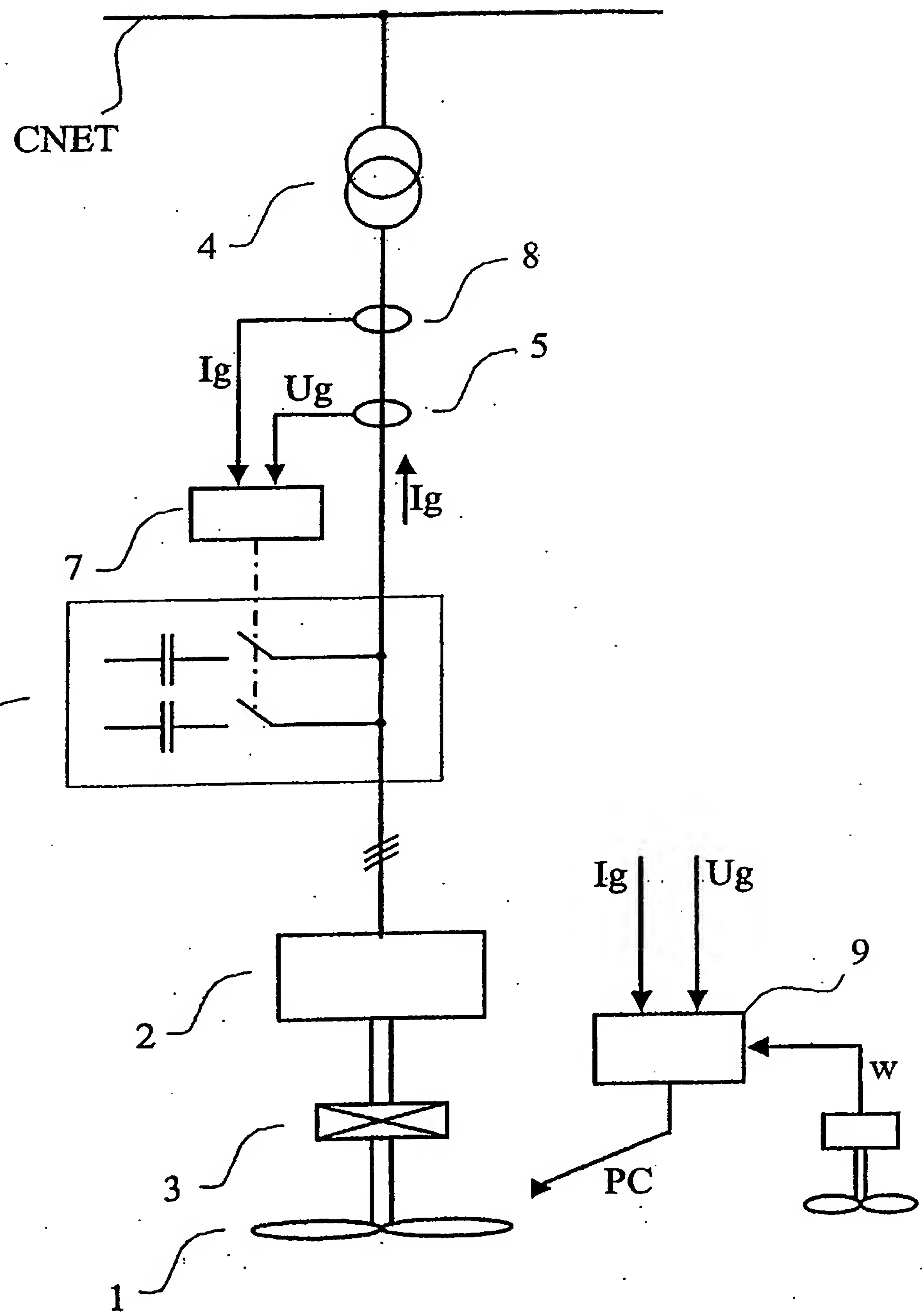
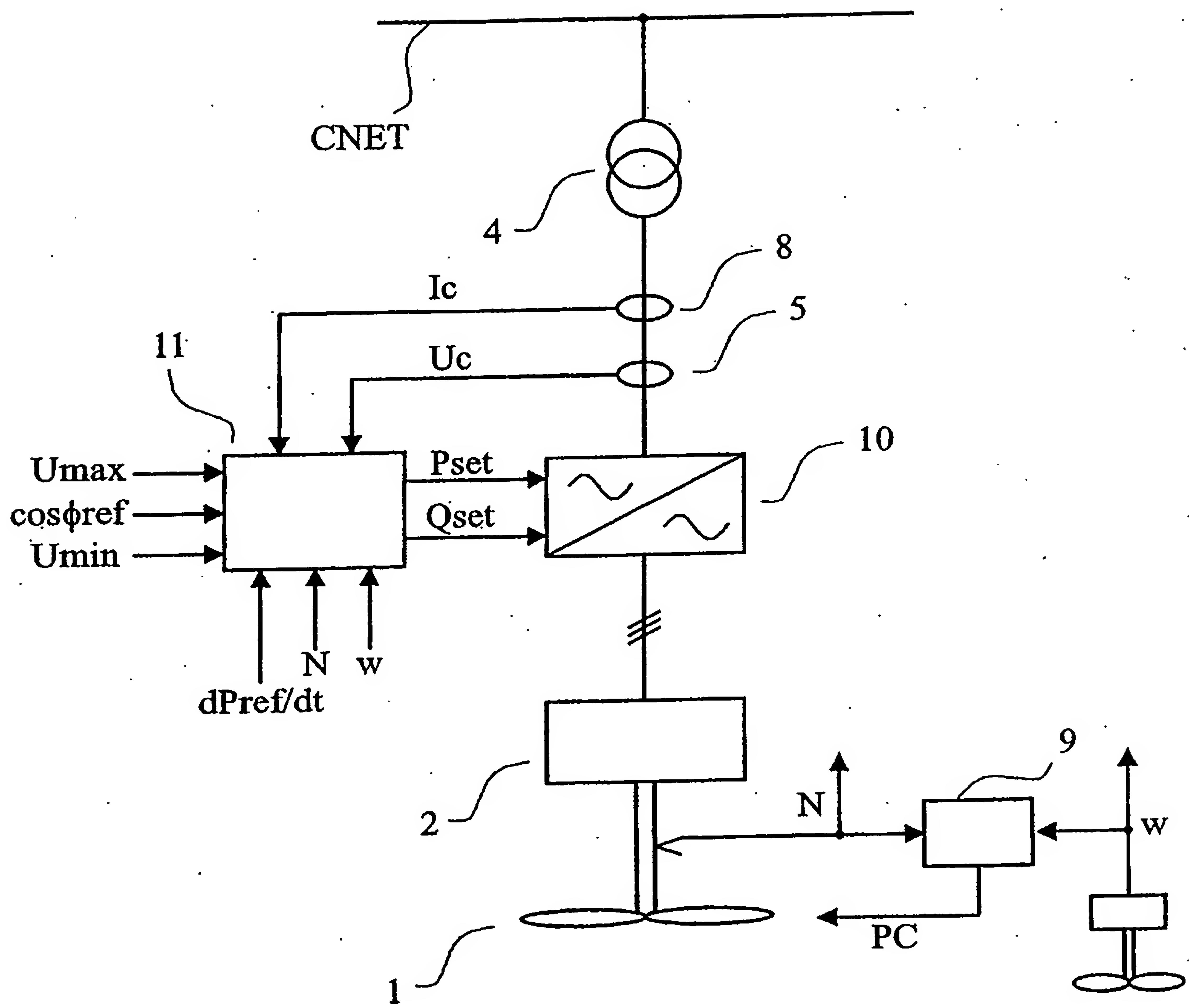


FIG 1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4
8
Ic
5
11
Uc
10
Umax
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Umin
Pset
Qset
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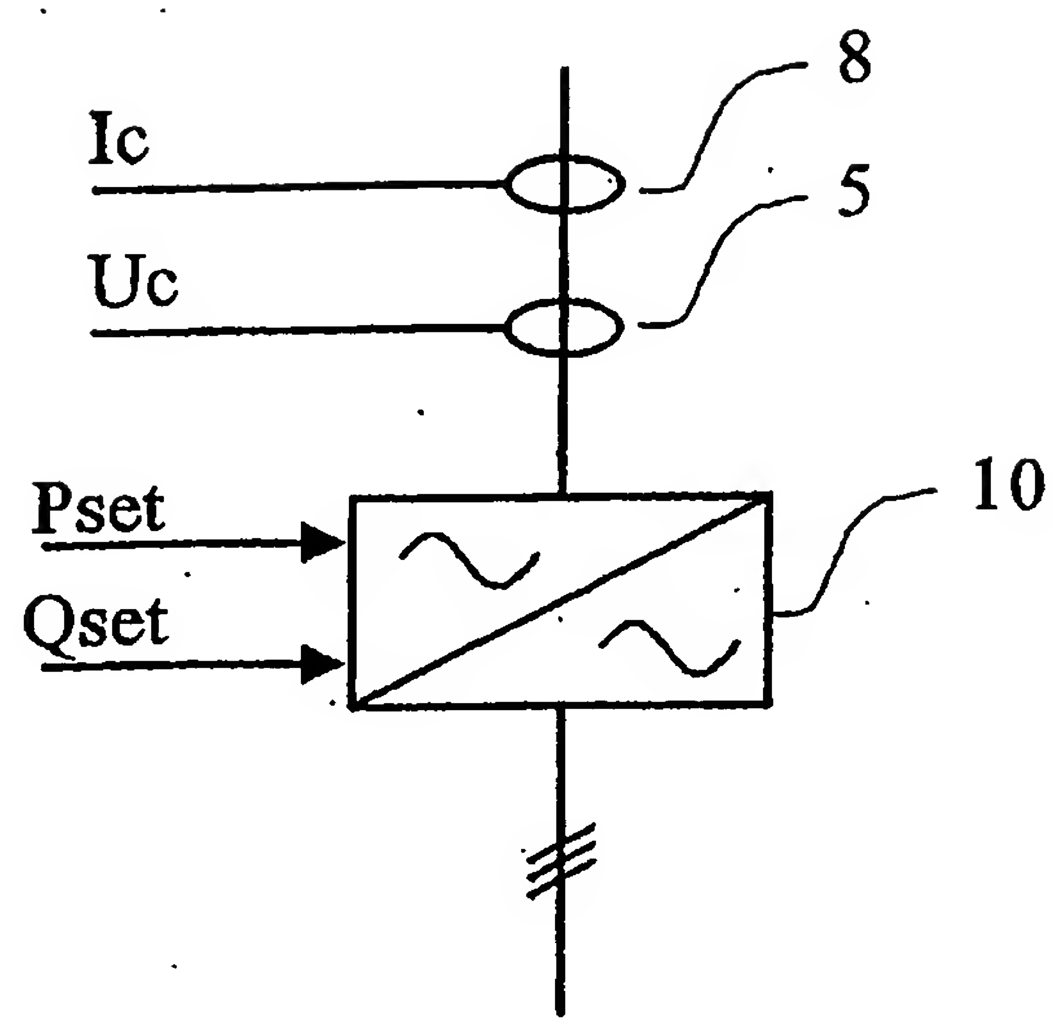
2
N
w
PC
1

FIG 2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8
5
Pset
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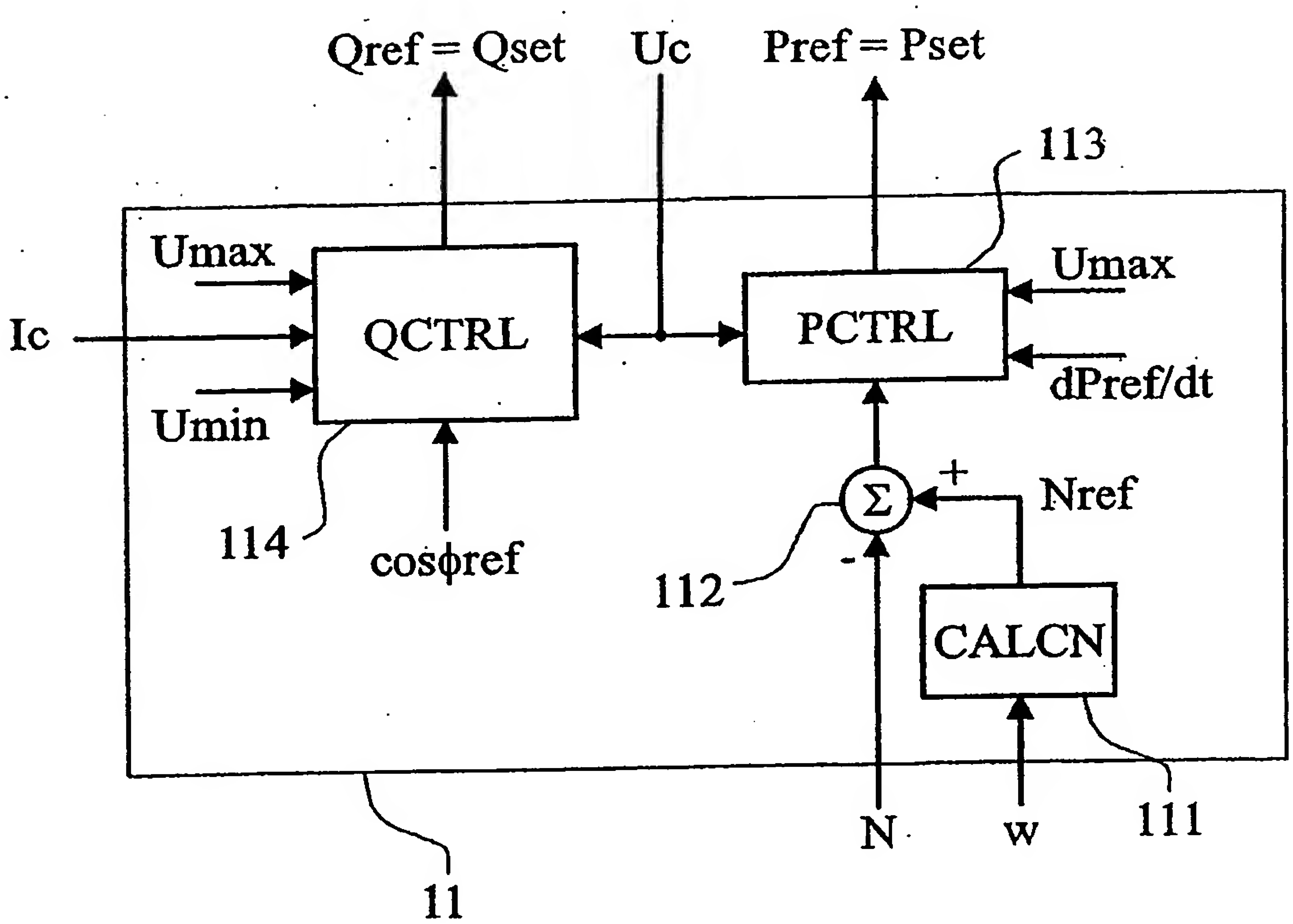
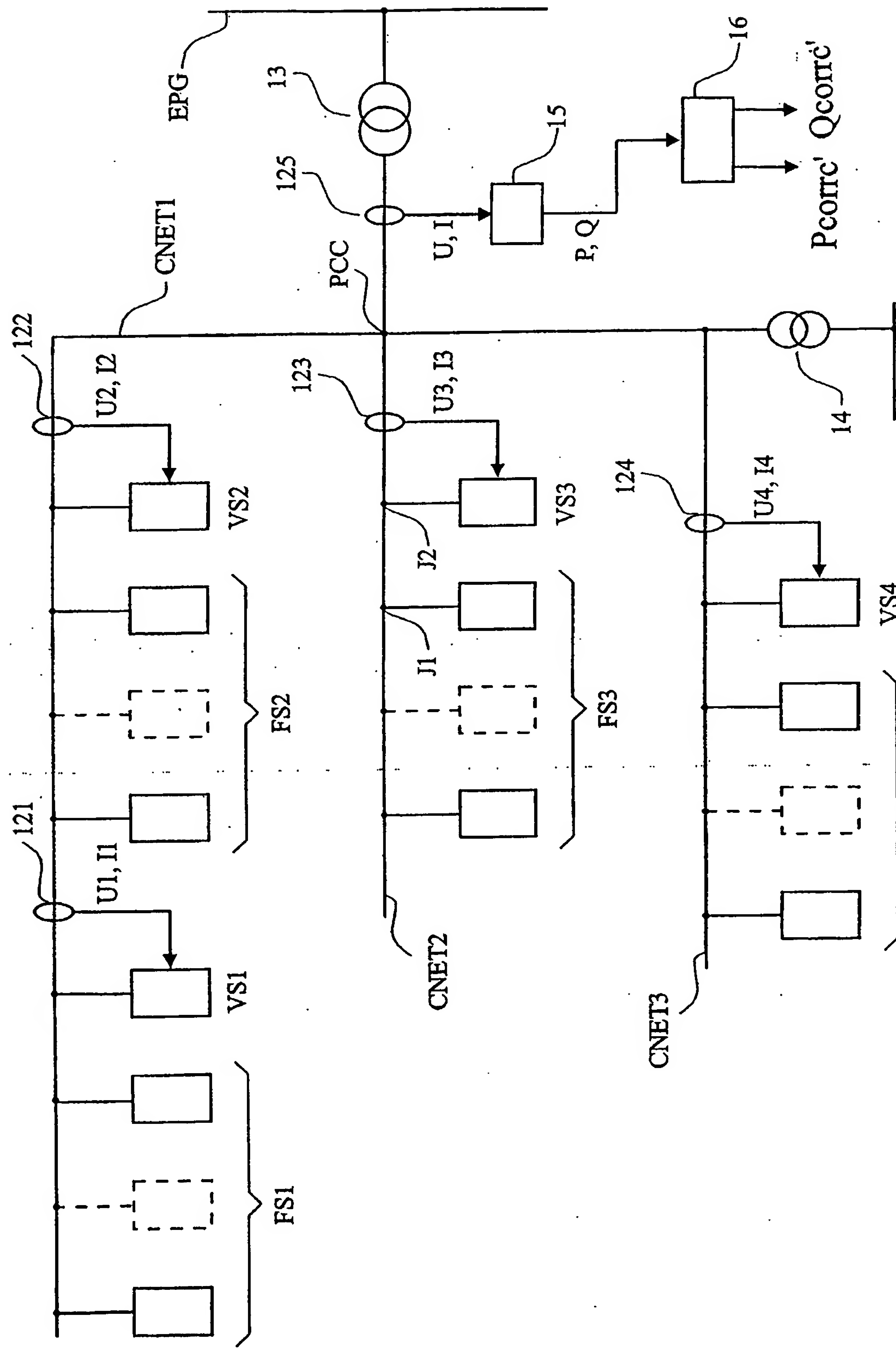

Qref = Qset
Uc
Pref = Pset
113
Umax
QCTRL
PCTRL
Ic
Umax
dPref/dt
Umin
+
Nref
114
cosφref
112
-
CALCN
111
N
w
11

FIG 3


EPG
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16
15
125
Pcorrc'
Qcorrc'
U, I
P, Q
CNET1
PCC
122
U2, I2
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U3, I3
14
LOCN
124
U4, I4
VS2
VS3
VS4
J2
J1
FS2
FS3
FS4
121
U1, I1
VS1
CNET2
CNET3
FS1

FIG 4

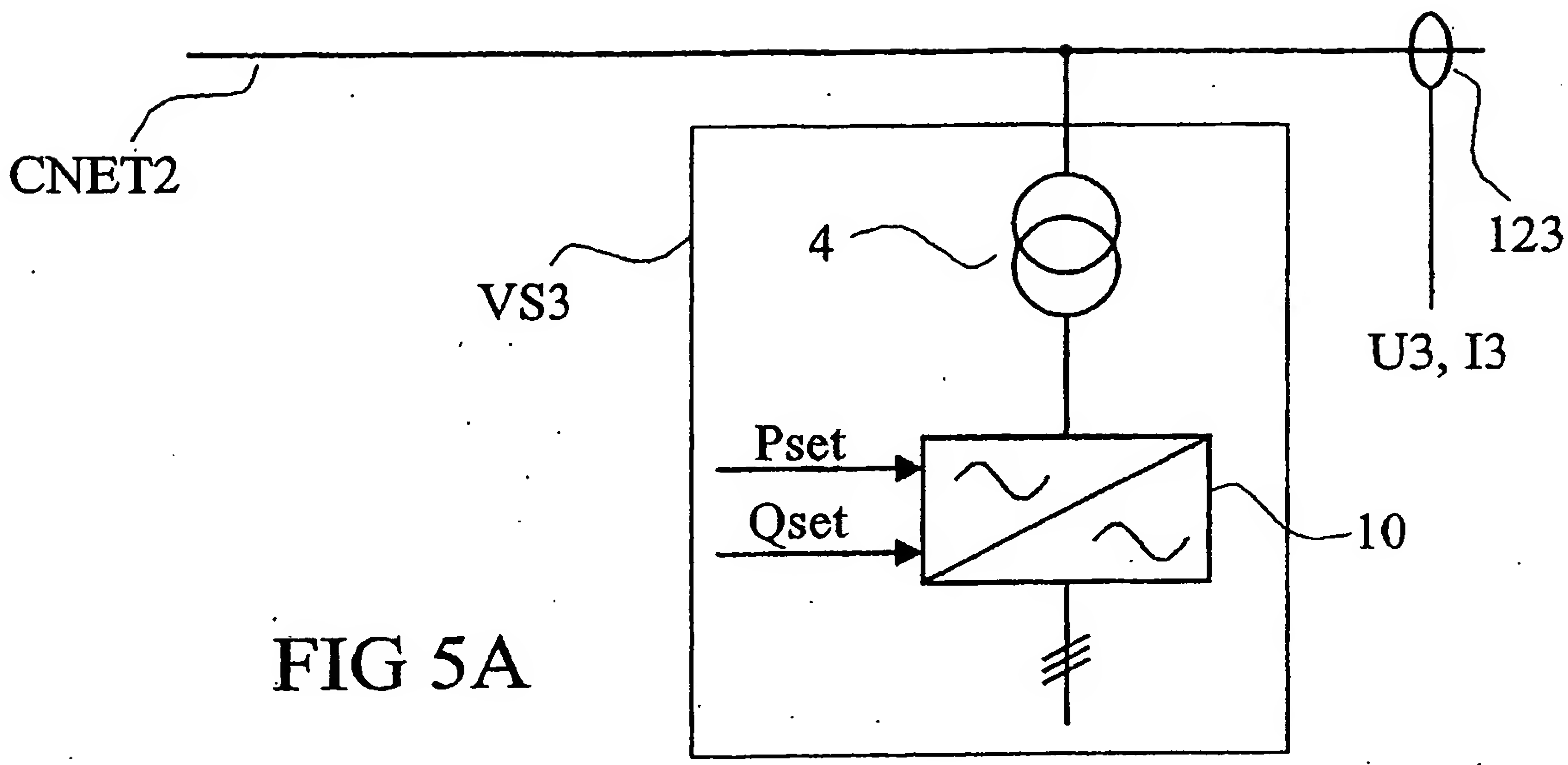
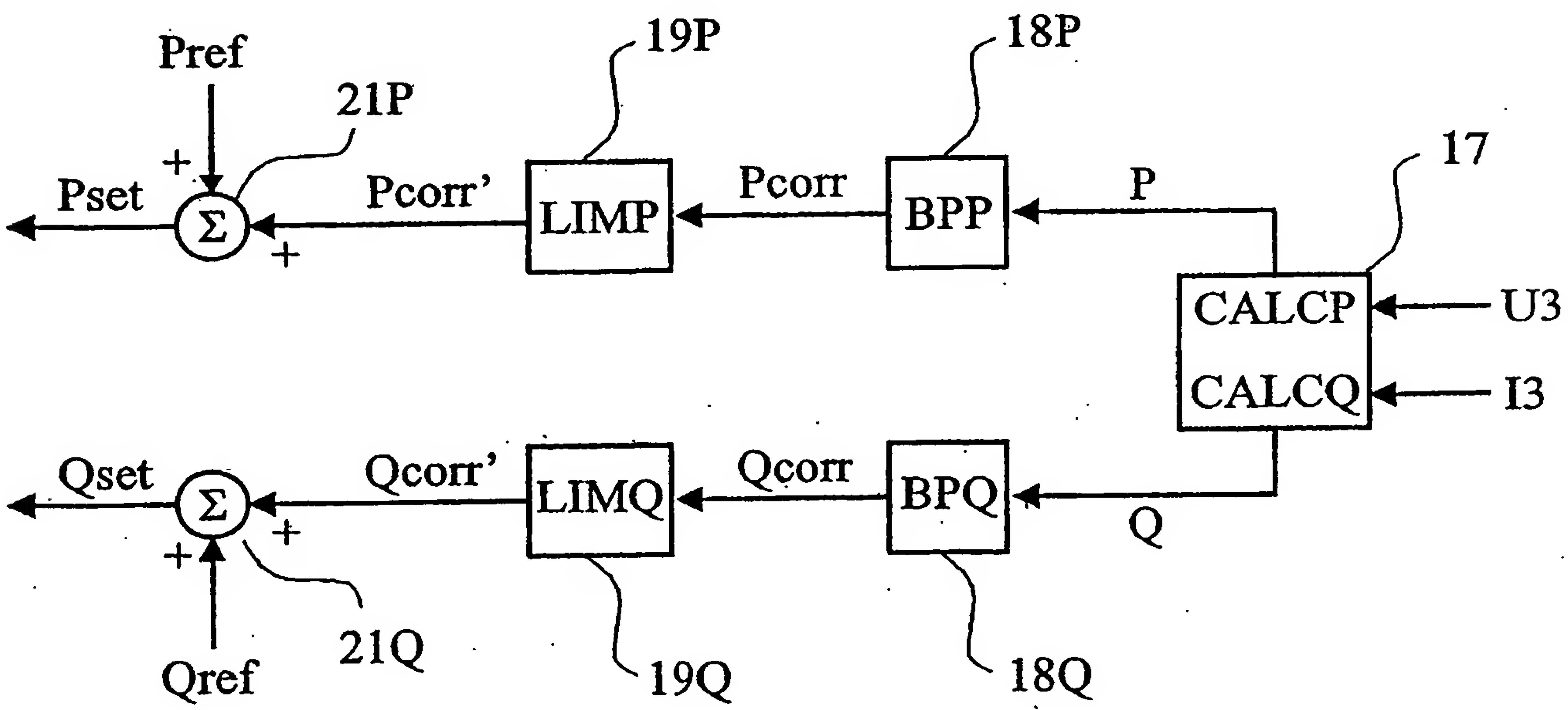

CNET2
VS3
4
123
U3, I3
Pset
Qset
10

FIG 5A


Pref
21P
19P
18P
17
+
Pset
Σ
+
Pcorr'
LIMP
Pcorr
BPP
P
CALCP
U3
CALCQ
I3
Qset
Σ
+
+
Qcorr'
LIMQ
Qcorr
BPQ
Q
Qref
21Q
19Q
18Q

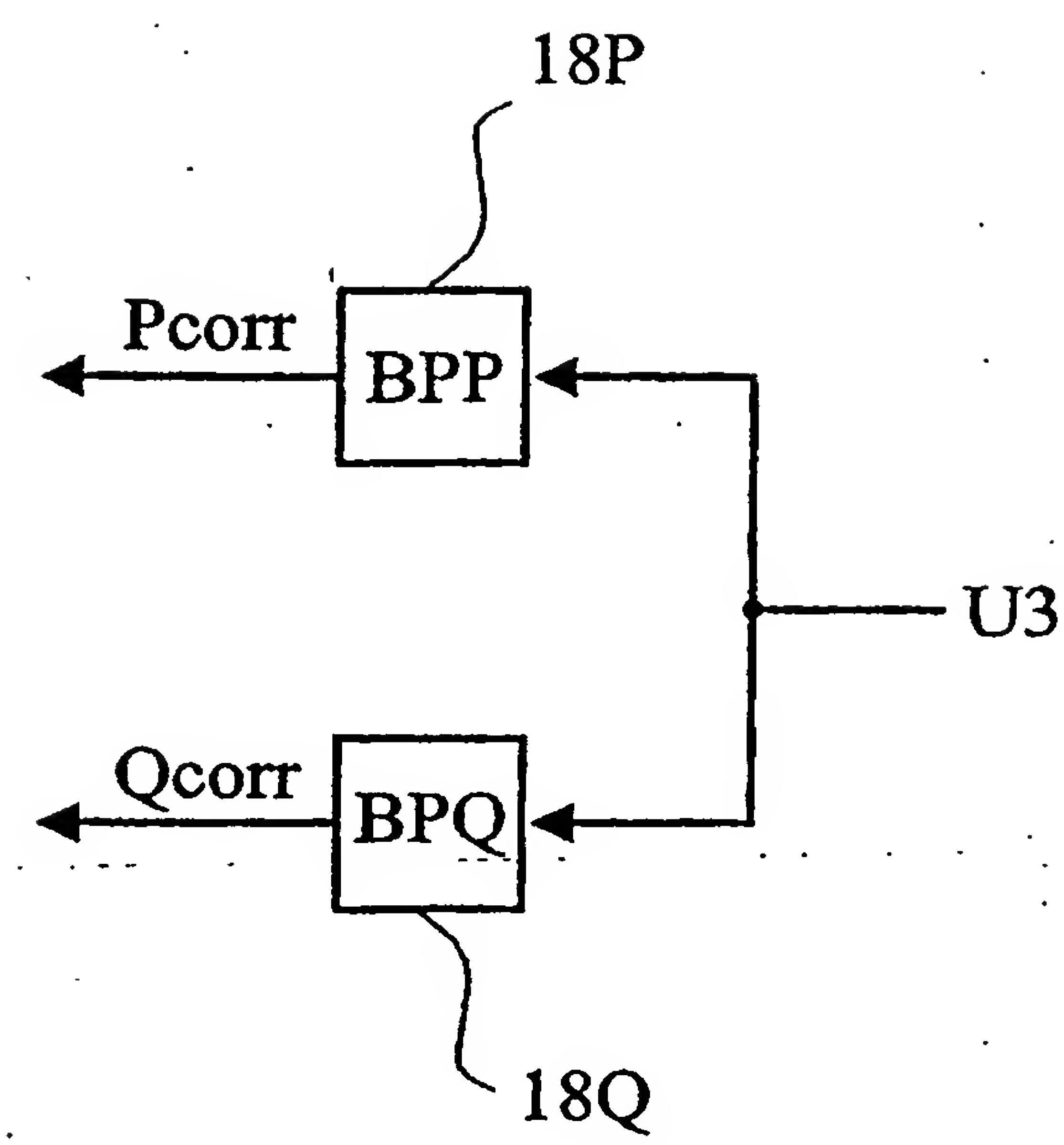


FIG 5B

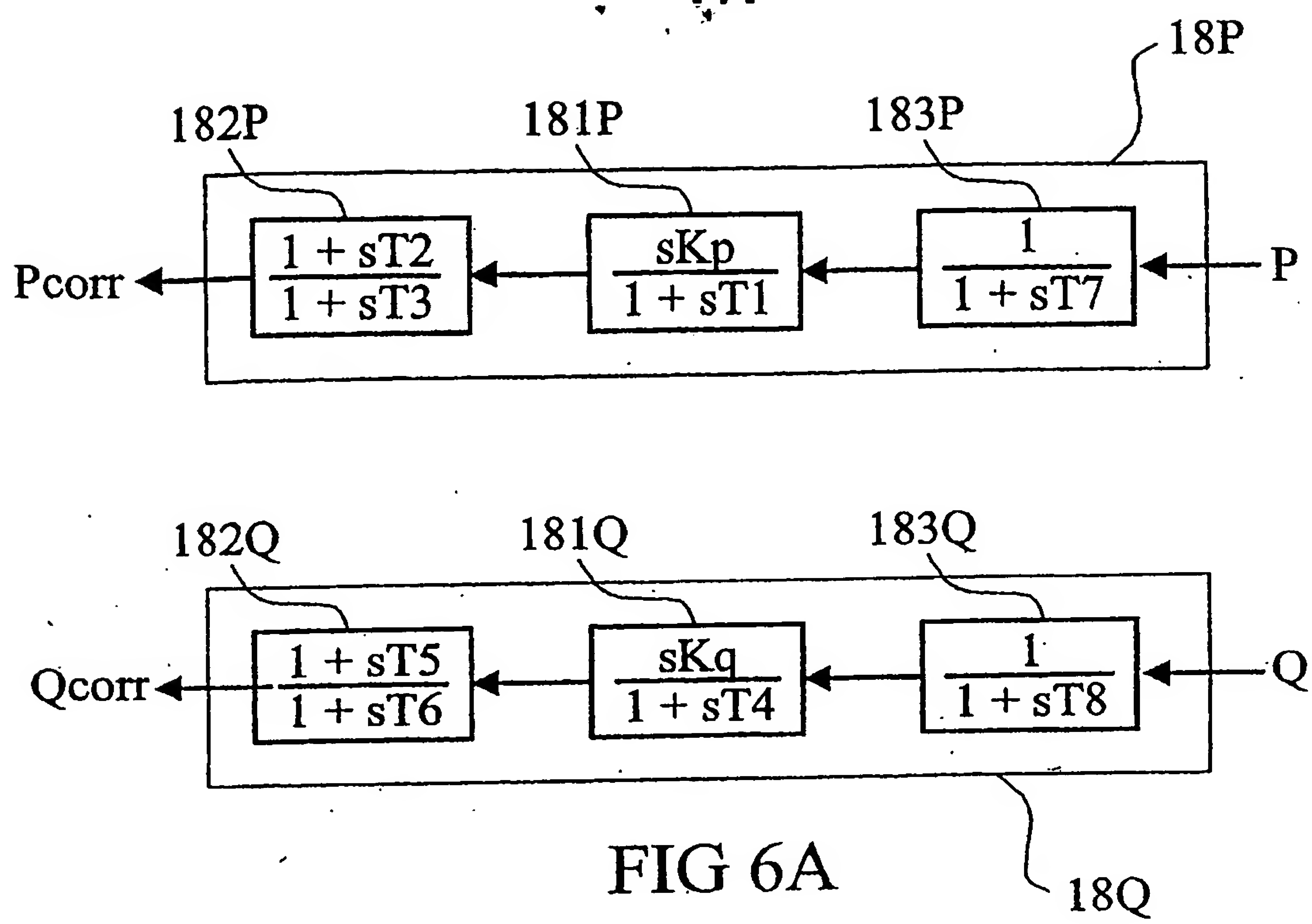

18P
182P
181P
183P
Pcorr
1 + sT2
1 + sT3
sKp
1 + sT1
1
1 + sT7
P
182Q
181Q
183Q
Qcorr
1 + sT5
1 + sT6
sKq
1 + sT4
1
1 + sT8
Q
18Q

FIG 6A

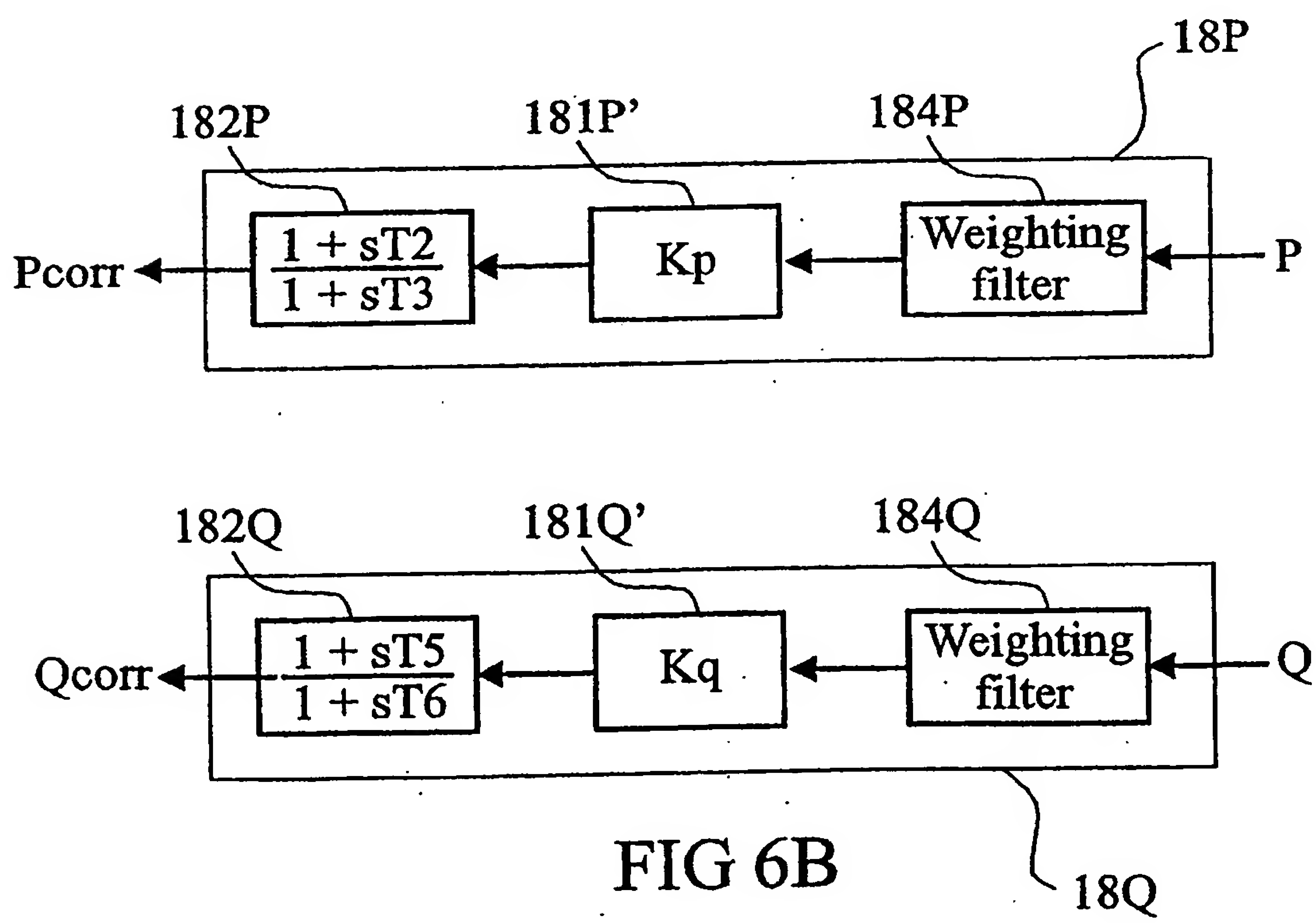

18P
182P
181P'
184P
Pcorr
1 + sT2
1 + sT3
Kp
Weighting filter
P
182Q
181Q'
184Q
Qcorr
1 + sT5
1 + sT6
Kq
Weighting filter
Q
18Q

FIG 6B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 01/00134

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G05F 1/70, H02J 3/38, H02P 9/48
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: G05F, H02J, H02P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4656413 A (F.J. BOURBEAU), 7 April 1987 (07.04.87), abstract --	
A	US 4525633 A (M.M. WERTHEIM ET AL), 25 June 1985 (25.06.85), abstract --	
A	US 4388585 A (F.J. NOLA), 14 June 1983 (14.06.83), abstract --	
A	EP 0280876 A1 (LOHER AKTIENGESELLSCHAFT ET AL), 7 Sept 1988 (07.09.88), abstract --	

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 June 2001	04-07-2001

Name and mailing address of the ISA/	Authorized officer
Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Dan Ionesco / MRo Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT
Information on patent family members

28/05/01

International application No.
PCT/NO 01/00134

Patent document cited in search report			Publication date	Patent family member(s)			Publication date
US	4656413	A	07/04/87	NONE			
US	4525633	A	25/06/85	NONE			
US	4388585	A	14/06/83	US	4417190	A	22/11/83
				US	4473792	A	25/09/84
EP	0280876	A1	07/09/88	SE	0280876	T3	
				AT	88600	T	15/05/93
				DE	3880349	A,T	27/05/93
				IL	81437	A	17/09/90
				US	4841218	A	20/06/89